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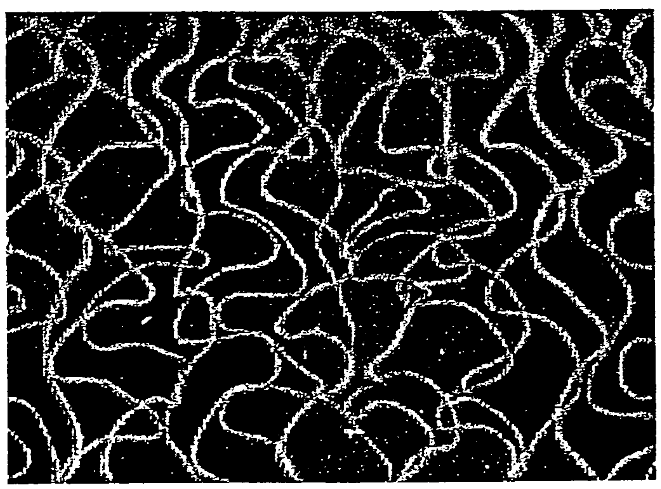
New Product Release

SOLID STATE DIETIP™

FEATURING

DURASTITCH™ TECHNOLOGY



Release Date: February 17, 1997 • **Released By**: Carin Uhlir, Marketing • **Approved By**: MAA
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J&M Laboratories

Positioning Strategy

- The solid state adhesive melt blowing dietip is a direct replacement for all other DFI and DFII dietips.
- It is intended for all new adhesive melt blowing applications. It will work for most existing markets.

Selling Arguments

- The dietip does not require air plates. Process air is delivered to the nosepiece via vectored air jets.
- Extremely robust extrusion process. The solid state fluid extrusion process for melt and process air is very reliable and cannot be upset by external influences. Even the most contaminated glue application environments are achieved with ease and consistent application patterns.
- Lower consumption of process air. The vectored air jets are more efficient in transferring spinning energy into the adhesive filaments. Hence the glue pattern has precise definition, excellent edge control and remarkable intermittent pattern control.

Options

- Standard dietip is made of brass
- Steel dietip
- Stainless steel dietip
- Partial dietips with holes drilled from side to center:
    - 5 hole
    - 4 hole
    - 3 hole
    - 2 hole
    - 1 hole

Cautions

The new solid state dietip should not be used in conjunction with other dietip/airplate combinations. The SSDT requires approximately 20% higher process air pressure but consumes less process air than older generations.

Explanation of Use

In the melt blowing of adhesives, a modular die concept is preferred over the conventional linear die concept. Modular melt blowing dies are disclosed in Patent # 5,145,689 and 5,445,509. The problem with modular melt blowing dies is that the user prefers a unitary application pattern or web structure without cross directional or machine directional irregularities, coupled with a segmented or modular die design. One way to achieve this is to keep the space between opening(s) between die tips to the same spacing as the center spacing of the opening(s) on the individual tips. This, however, limits the opening(s) spacing to 7 openings per tip, each tip being .740" wide.
Due to the rapidly diminishing air gap on the two edges of each tip, the last filament on each edge of the tip does not receive as much process air flow. This reduced flow results act in lower aerodynamic drag forces and hence a slower filament attenuation speed. The filaments are "lazy" and are not as controlled as the filaments in the center.
Also air plates are used in melt blowing. The air plates are very precisely machined metal pieces that are manufactured to extremely tight tolerances. They employ an air gap of about 0.007" that has to be meticulously maintained and kept debris free. In daily production environments, the air plates become contaminated and have to be cleaned on a frequent basis. This causes the machine to stop and accumulates unwanted downtime.

Experiment 1

An experiment was made with the following criteria:
2 dietips, 0.740" wide each, mounted on a die body on 0.750" centers.
Each dietip has 6 openings of 0.020" diameter on 0.104" centers. Each dietip has 0.100" undrilled area on the outer 2 edges of the nosepiece.
Each dietip has 16 air openings per side, exiting on each side at the base of the nosepiece.
The air holes are at the same angle alpha as the nosepiece section.
The air holes have a second angles beta, B1, B2, B3, B4, B5, B6, B7, B8 that arranges the air holes in an arc pattern from side to side. The angle beta causes the filaments to move outward, away from the center of the dietip. The air deposits the filaments in a pattern that is 0.750" wide, even though the spacing of the first melt flow opening to the last melt flow opening in the nosepiece is only 0.520".

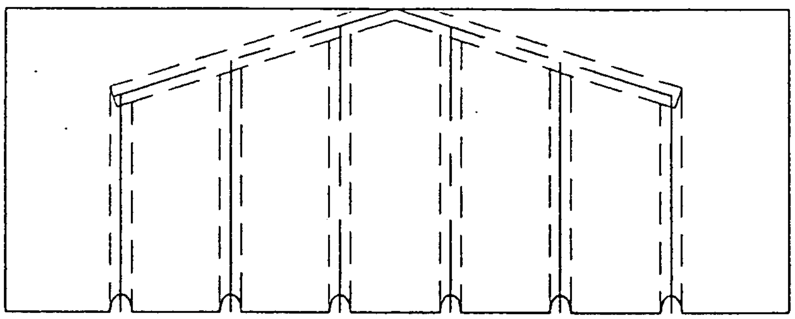
Temperatures	Mass Flow
PreMelt = 270 F	Qm = 10 grams per minute or 1.66 grams per hole per minute
MainMelt = 270 F	Qpa = 0.5 scfm
Hose = 270 F	Pressures
Die = 270 F	Ppa = 6 psig
Air Heater = 280 F	Pm = 150 psig

Result

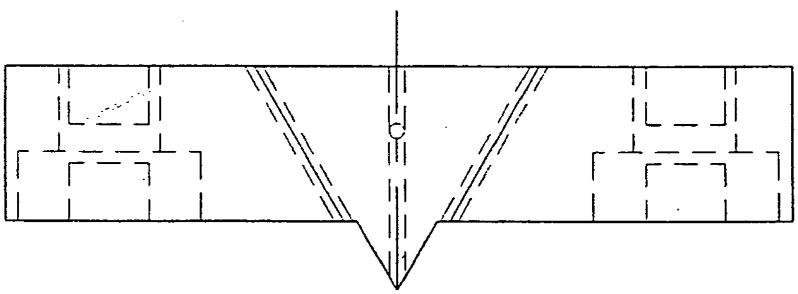
The pattern produced was even in cross direction and machine direction. Each filament makes a sinusoidal wave pattern as it is deposited onto a moving substrate. None of the filaments overlap each other. The last filament from one modular die and the first filament from the next modular die are deposited the same as the inner filaments. No irregularities in machine or crossweb uniformity can be detected in the applied pattern.

Novelty

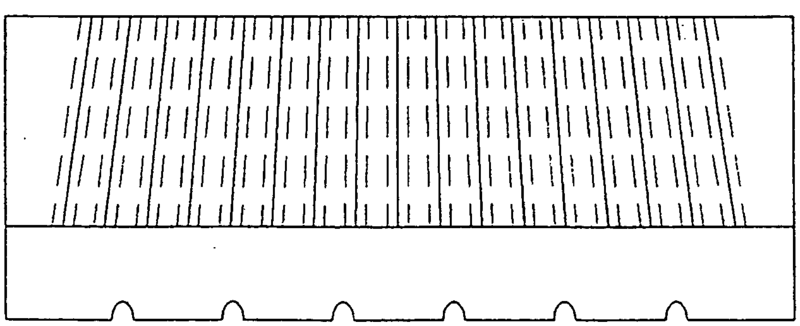
Apparatus constructed in accordance with this disclosure represent a novel method of dispensing polymers into filaments, while maintaining extreme pattern accuracy and unitary web or pattern construction with segmented modular die design. The apparatus according to the present invention also eliminates the use of small tolerance air plates and all adjustment that goes with air plates. The melt openings are machined at exact coordinates and the air holes are machined at exact coordinates, making the dietip constructed according to this invention a solid state melt blowing die.



Front view of the mathematically modeled coathanger distribution cavity in the solid state dietip



Side view of the solid state dietip



Front view of the solid state process air distribution system

DuraStitch™

Thermoplastic Stitching Technology from J&M Laboratories

DuraStitch™ represents the culmination of many years of research and development. Synthetic fiberization for Hot Melt adhesives began in the 1980's with spiral technology and continued with the development of Hot Melt adhesive melt blowing technology by J&M known as DuraFiber™. Other hot melt fiberization systems also became available in the market place. These systems are known as AMBI Lamination Fiberization dies made and sold by J&M Laboratories, DynaFiber, a J&M Laboratories hot melt fiberization platform sold under private label by ITW Dynatec, and Control Coat sold by Nordson corporation under license from J&M Laboratories.

The new DuraStitch™ technology represents the perfect combination of spiral and meltblown hot melt application patterns. DuraStitch™ produces very defined, high speed, stitch like hot melt adhesive patterns. The patterns exhibit higher filament frequency than spiral with the reliability, robustness and longevity of the meltblown process. Unlike the spiral technology, the DuraStitch™ process is not dependent on viscosity, throughput and temperature to produce a repeatable hot melt pattern. Like the meltblown process, the pattern always stays in target range regardless of process adjustments.

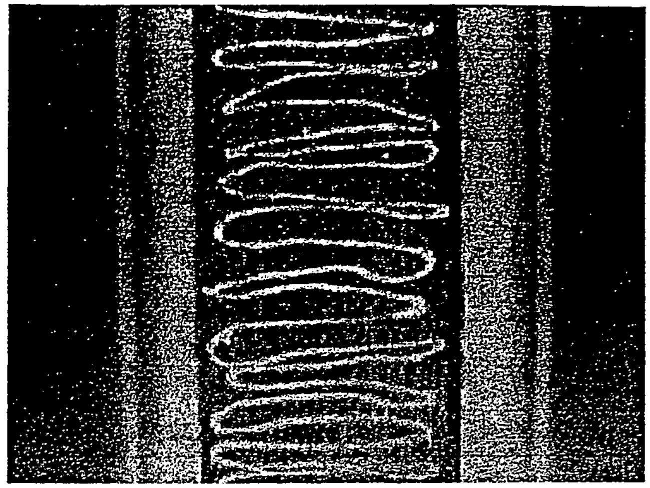
The following characteristics are important in non-contact, air assisted type application of hot melt:

Hot Melt Pattern Property	Spiral	DuraFiber	DuraStitch
Side Edge accuracy	+/- 0.030", 0.75 mm	+/- 0.030", 0.75 mm	**+/- 0.020", 0.5mm**
Pattern width accuracy	+/- 0.030", 0.75 mm	+/- 0.030", 0.75 mm	**+/- 0.020", 0.5mm**
Pattern start accuracy	+/- 0.200", 5 mm	+/- 0.200", 5 mm	**+/- 0.125", 3 mm**
Pattern end accuracy	+/- 0.200", 5 mm	+/- 0.200", 5 mm	**+/- 0.125", 3 mm**
Hotmelt add-on range per module at 1000 psi, 68 bar max. pressure	0 - 75 grams per minute	0- 300 grams per minute	**0-150 grams per minute**
Pattern air consumption	0-1 scfm per tip	0-1 scfm per tip	**0-0.8 scfm per tip**
Cross directional adhesive filament frequency, CDAFF at 1000 feet per minute	4 to 6 swirls per inch, 26 mm	20 to 200 filaments per inch, 26 mm	**10 to 25 crossing filaments per inch, 26 mm**
Machine directional adhesive filaments, MDAF	1 per tip based on 0.75", 19 mm module width	6 to 22 per tip, based on 0.75", 19 mm module width	**1 to 6 per tip based on 0.75", 19 mm module width**
Filament diameter	0.005", 0.125mm - 0.030", 0.75 mm	5 micron to 0.030", 0.75 mm	**0.005", 0.125mm - 0.030", 0.75mm**
Air to melt ratio, lbm(air):lbm(melt)	1:9 typical	1:9 typical	**1:8 typical**
Air to melt ratio linearity during parent machine ramp up	depends on accuracy of electro-mechanics	very linear due to inherent technology	**very linear due to inherent technology**
Viscosity limitations	very dependent	some dependency	**virtually no dependency**
Adhesive rheology limitations	very dependent	some dependency	**virtually no dependency**

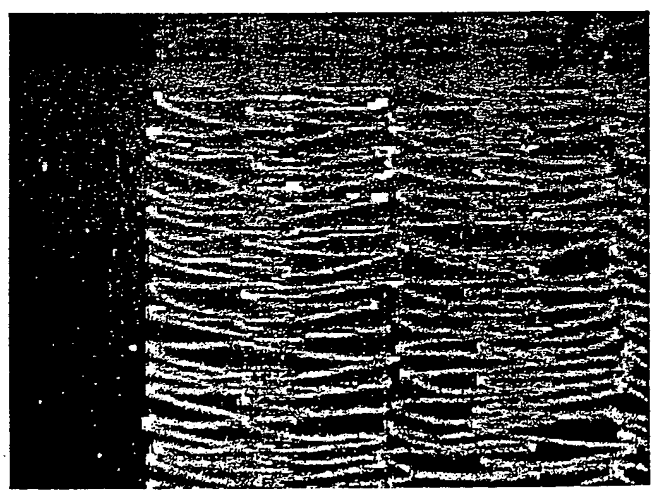
DuraStitch™ accomplishes all of these variables in a controlled fashion, giving the user the ultimate in pattern flexibility.

The following represents the current configurations for the DuraStitch™ technology. The intermittent modular valve system is based on the proven DuraFiber II platform:

DuraStitch™
Shown:
Diaper Leg Elastic Attachment pattern
8 grams per minute
650 feet per minute
22 stitches (CDAF - cross directional adhesive filaments) per inch, 26 mm



DuraStitch™
Shown:
3 module applicator
16 grams per module per minute
650 feet per minute
25 stitches (CDAF - cross directional adhesive filaments)per inch, 26 mm



Thermoplastic stitch pattern for:

- Diapers
    - Elastic leg
    - Standing leg cuff
    - Construction
    - Transfer layer to tissue
    - Transfer layer to core
- Adult incontinent products
    - Construction
    - Elastic leg
    - Core stabilization
- Bag market
- Fem-Hy market

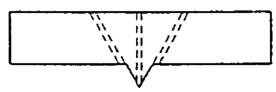
Note

Please contact all customers that currently have older generation dietips for DFI or DFII and sell them the new solid state dietips.

Pricing

C10151 State DieTip

(DieTip Only)



J&M Part Number	Description	Multiplier Sell Price
C10151-01	Solid State Modular Die Tip Steel 1 x 20 x 34 x 20	$284.38
C10151-01-B	Solid State Modular Die Tip Brass 1 x 20 x 34 x 20	$227.50
C10151-01-S	Solid State Modular Die Tip Stainless Steel 1 x 20 x 34 x 20	$341.25
C10151-02	Solid State Modular Die Tip Steel 2 x 20 x 34 x 20	$284.38
C10151-02-B	Solid State Modular Die Tip Brass 2 x 20 x 34 x 20	$227.50
C10151-02-S	Solid State Modular Die Tip Stainless Steel 2 x 20 x 34 x 20	$341.25
C10151-03	Solid State Modular Die Tip Steel 3 x 20 x 34 x 20	$284.38
C10151-03-B	Solid State Modular Die Tip Brass 3 x 20 x 34 x 20	$227.50
C10151-03-S	Solid State Modular Die Tip Stainless Steel 3 x 20 x 34 x 20	$341.25
C10151-04	Solid State Modular Die Tip Steel 4 x 20 x 34 x 20	$284.38
C10151-04-B	Solid State Modular Die Tip Brass 4 x 20 x 34 x 20	$227.50
C10151-04-S	Solid State Modular Die Tip Stainless Steel 4 x 20 x 34 x 20	$341.25
C10151-05	Solid State Modular Die Tip Steel 5 x 20 x 34 x 20	$284.38
C10151-05-B	Solid State Modular Die Tip Brass 5 x 20 x 34 x 20	$227.50
C10151-05-S	Solid State Modular Die Tip Stainless Steel 5 x 20 x 34 x 20	$341.25
C10151-06	Solid State Modular Die Tip Steel 6 x 20 x 34 x 20	$284.38
C10151-06-B	Solid State Modular Die Tip Brass 6 x 20 x 34 x 20	$227.50
C10151-06-S	Solid State Modular Die Tip Stainless Steel 6 x 20 x 34 x 20	$341.25

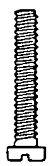
NOTE: Prices shown reflect <u>multiplier</u> price. Appropriate multiplier should be applied at time of quotation.

O-Ring, Qty 1

B10295 Solid State DieTip Assembly

(Spinpack Assembly)

Dietip, Qty 1



Screw, Qty 4

J&M Part Number	Description	Multiplier Sell Price
B10295-01	Assy, SP Solid State Steel 1 x 20 x 34 x 20	$286.43
B10295-02	Assy, SP Solid State Brass 1 x 20 x 34 x 20	$229.55
B10295-03	Assy, SP Solid State Stainless Steel 1 x 20 x 34 x 20	$343.30
B10295-04	Assy, SP Solid State Steel 2 x 20 x 34 x 20	$286.43
B10295-05	Assy, SP Solid State Brass 2 x 20 x 34 x 20	$229.55
B10295-06	Assy, SP Solid State Stainless Steel 2 x 20 x 34 x 20	$343.30
B10295-07	Assy, SP Solid State Steel 3 x 20 x 34 x 20	$286.43
B10295-08	Assy, SP Solid State Brass 3 x 20 x 34 x 20	$229.55
B10295-09	Assy, SP Solid State Stainless Steel 3 x 20 x 34 x 20	$343.30
B10295-10	Assy, SP Solid State Steel 4 x 20 x 34 x 20	$286.43
B10295 -11	Assy, SP Solid State Brass 4 x 20 x 34 x 20	$229.55
B10295-12	Assy, SP Solid State Stainless Steel 4 x 20 x 34 x 20	$343.30
B10295-13	Assy, SP Solid State Steel 5 x 20 x 34 x 20	$286.43
B10295-14	Assy, SP Solid State Brass 5 x 20 x 34 x 20	$229.55
B10295-15	Assy, SP Solid State Stainless Steel 5 x 20 x 34 x 20	$343.30
B10295-16	Assy, SP Solid State Steel 6 x 20 x 34 x 20	$286.43
B10295-17	Assy, SP Solid State Brass 6 x 20 x 34 x 20	$229.55
B10295-18	Assy, SP Solid State Stainless Steel 6 x 20 x 34 x 20	$343.30

NOTE: Prices shown reflect <u>multiplier</u> price. Appropriate multiplier should be applied at time of quotation.

Advanced Hot Melt Adhesive Melt Blowing Technology

By:

Joel Saine	Product Development Manager – J&M Laboratories
John McCulloch	Consultant to J&M Laboratories
Martin A. Allen	President – J&M Laboratories
Mehmet Sinangil	Research Scientist – J&M Laboratories

Abstract

Melt blowing and adhesive technologies are both relatively old. Melt blowing of nonwovens being first demonstrated in the 1970's by Exxon Chemical (1)(2) and adhesive technologies much earlier. Exxon demonstrated two different regimes of operation. The high flow regime, which is most commonly used for polymer melt blowing, and a low air flow, lower energy regime which at the time generated little commercial interest. Synthetic fiberization for hot melt adhesives was introduced with the development of adhesive melt blowing technology (AMBI™) in the late 1980's by J&M Laboratories. This product release was revolutionary due to the reduction in glue consumption (up to 30%) while maintaining equal or better bond strengths than present glue applicators offered at that time. Shortly afterwards, J&M Laboratories extended the technology into a modular platform referred to today as DuraFiber ®. DuraFiber offers the flexibility of application technologies such as bead, swirl, fine line, coating and Meltblown within the same glue applicator, reducing product change over times substantially. After the release of DuraFiber, a new MeltBlown process referred to as DuraStitch™ I was developed. DuraStitch was another breakthrough in improving the Melt blowing process by further reducing energy consumption and offering precise control of how the filaments are dispensed to the substrate.

J & M Laboratories, in development of the DuraStitch technology will detail advances in both the adhesive equipment, and in the understanding of the melt blowing process during the decade since the introduction of AMBI dies.

1. Introduction

Shambaugh et al, in their studies on the melt blowing process (3,4,5) during the mid 1980's, postulated three regions (Fig. 1) of operations. Where a broad distribution of fiber sizes is obtained in the high airflow region (III), whereas the fiber distribution in the low air flow region (I) is almost monodisperse. He also stressed that the efficiency of the melt blowing process depends on the least amount of air to produce a kilogram of product of a given fiber size as well as stressing the critical importance of polymer viscosity.

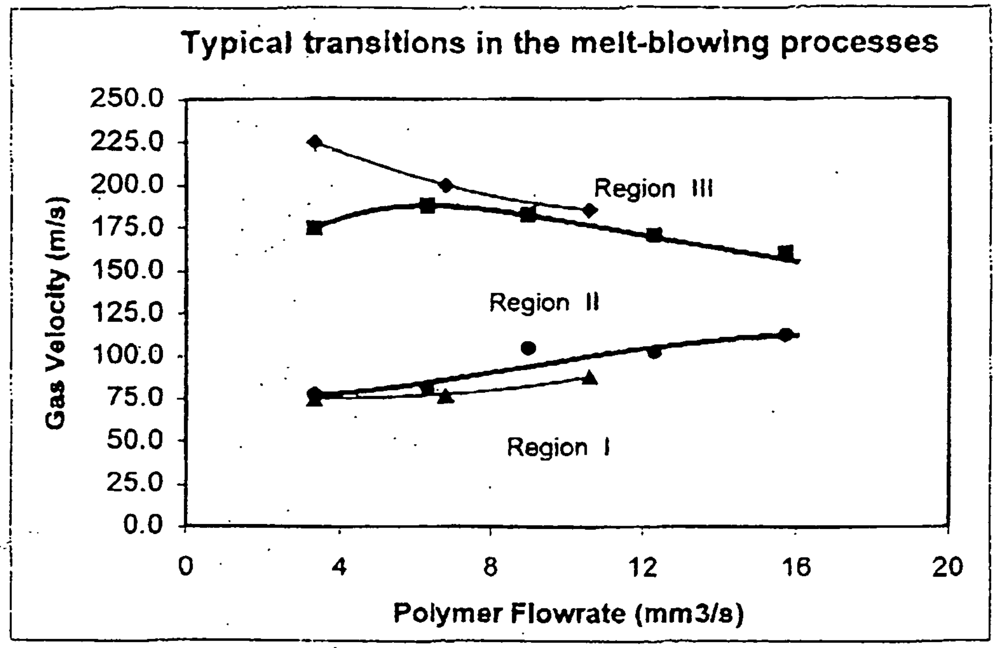


Figure: 1

In the late 1980's J & M Laboratories recognized the potential of the low flow regime of the Melt blowing process to apply adhesives to substrates by combining Melt blowing process technology and adhesive technology. J and M developed an intermittent adhesive Melt blowing die, which differed from the conventional polymer Melt blowing die with at least two significant modifications:

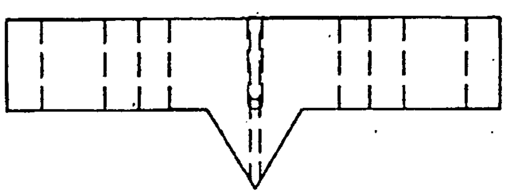
- The Die was divided into several 1-2 inch side by side segments.
- An internal valve was incorporated into each segment.

J and M also provided the die with "quick change features". The innovative AMBI technology (6) provided laminators several key advantages over existing glue applicators offered at that time:

- Reduced glue consumption (up to 30%).
- Equal or better bond strengths despite using less glue.
- Patterned deposition of the adhesive fibers are readily attainable.
- Heat sensitive substrates are not damaged by the relatively small (20-100 micron) fibers.

2. History – Development of advanced adhesive Melt Blowing technology

AMBI equipment, because of it's rugged, stainless steel construction, is still very valuable for users who operate at high temperatures, in corrosive environments or for extended periods of time. J & M however continued to advance the technology to develop lower cost, more flexible adhesive fiberization equipment and extend the technology into a modular platform referred to today as DuraFiber. DuraFiber now offered the flexibility of application technologies such as bead, swirl, fine line, coating and conventional random lay down Meltblown within the same glue applicator, reducing product change over times substantially.
The DuraFiber melt tip is similar to a polymer melt-blowing nosepiece, excluding the secondary (cooling) air. The initial melt tip (Fig. 2) used an air plate design, and typically had 1 to 18 holes (linear spinnerets) with two curtain type heated air streams.



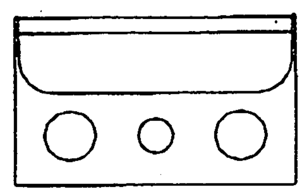


Figure 2: Side view of MeltBlown tip

Air plate

The heated process air is forced (under pressure) across both sides of the tip crest, as shown in Figure 3, with the primary function of drawing the extruded adhesive into fibers and carrying the filaments to the substrate in a controlled manner. The air that exits from the base of the apex is referred to as lateral drawing air. The lateral drawing air flows up the sidewalls of the crest. At the top of the crest, two things happen. Where no melt flow is present the lateral air from both sides of the crest combine and form what we have termed linear drawing air. This is the air that produces the major draw and aerodynamic flapping components. This is what causes the filaments to be deposited in a sinusoidal pattern. The second thing that happens is that where there is melt, the lateral air cannot flow through the melt, so the lateral air streams cannot combine into linear drawing air. This air is dissipated according to normal jet behavior. Since there are many orifices side by side, the filaments are laid in an overlapping fashion on the substrate.

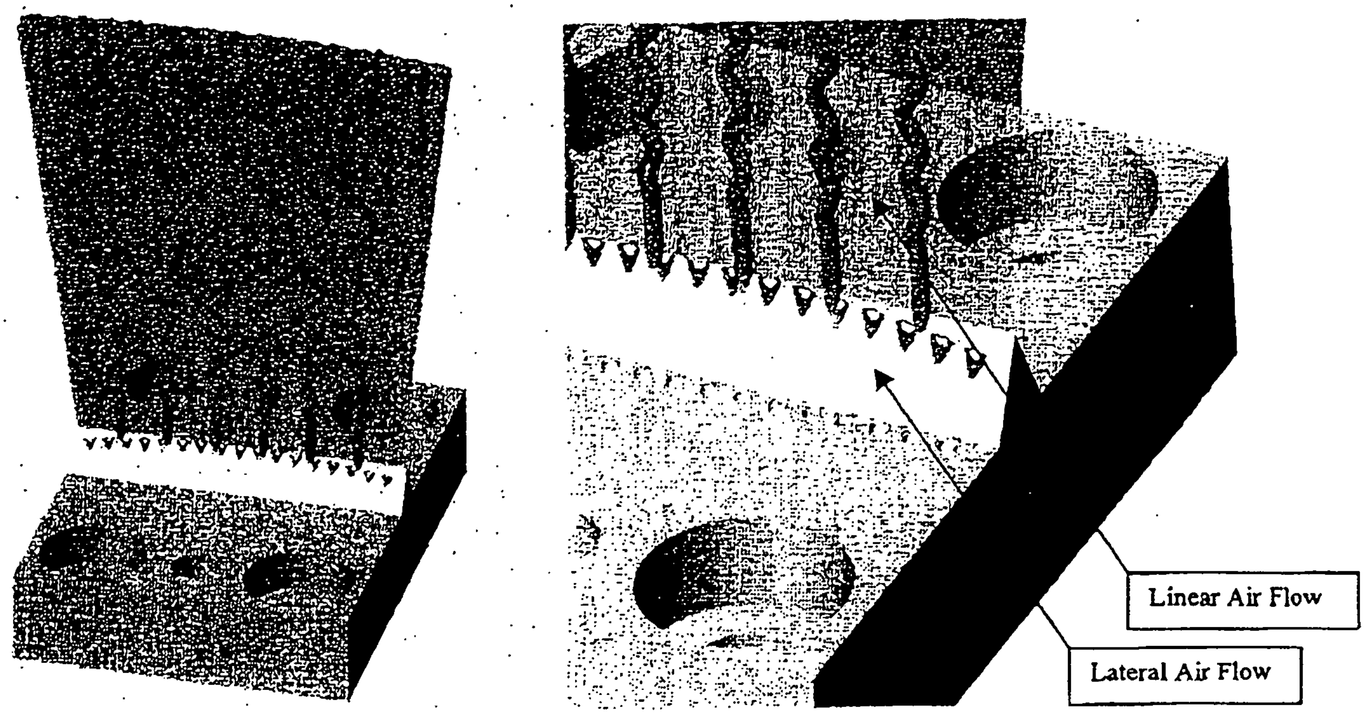


Figure: 3 (DuraStitch II Design)

Experimental studies and theoretical calculations have proven that the level of fiber interaction and lay down density is a function of:

- The ratio of the process air volume with respect to the velocity at which it effects the adhesive melt.
- Melt volume
- And the forming distance at which the applicator is placed from the substrate are also key considerations.

It was also discovered that applicator tips requiring multiple filament holes had difficulties in maintaining efficient airflow on the outer edges of the air plates. Due to the turbulent behavior of the air, the high velocity airflow contacts the low velocity airflow close to the outer wall region inside the air plate. This contact causes a rotation in the transverse vortex. This vortex increases in size with flow and moves away from the edges (8). This vortex and others are collected in the center of the flow, which enables only the center portion of the air plate to have the correct air flow pattern. This problem was overcome by changing the angle at the outer edges (as shown in Figure 4) so that the fibers are all deposited on the substrate surface under the same airflow conditions.

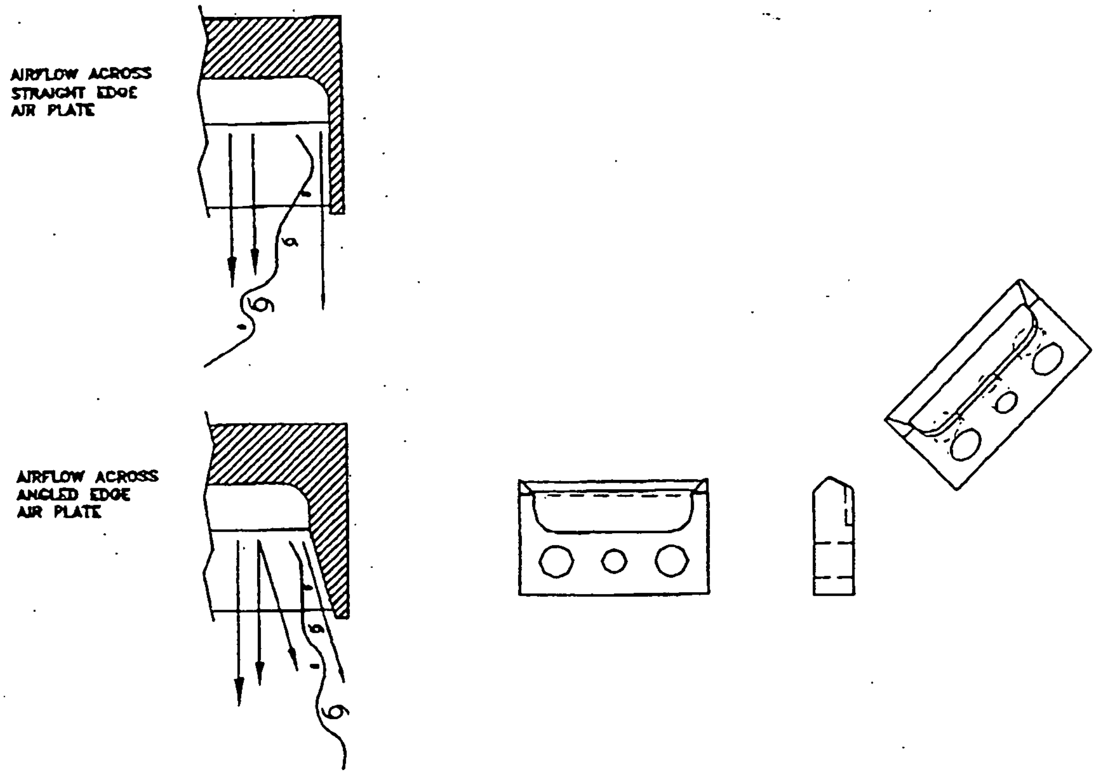


Figure: 4

In practice it was also found that the precisely machined air plates (.007" air gap) needed to be meticulously maintained and kept debris free. This problem was overcome with the release of the Solid State DuraStitch II design. Instead of using a 0.007" X 0.72" trapezoid shaped air curtain on both side of the crest, 17 air holes (Figure 5) with equal diameter and equal center to center distance and 1° increment per hole have been drilled on both side of the crest.

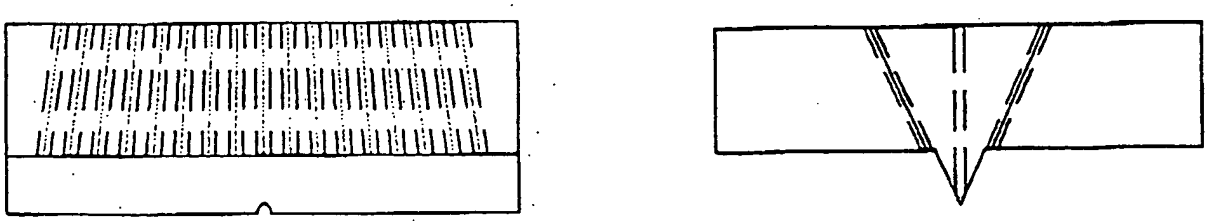


Figure: 5 (DuraStitch™ II Design)

A design improvement was made (DuraStitch III) to decrease process air consumption even further and increase fiber manipulation efficiency by transferring the air holes to the crest (Figure 6), next to the melt holes. Thus decreasing the velocity drop due to the shorter travel length of the air to the crest. Angling the air holes towards the melt hole can further increase the effect of "Lift and Drag" forces on the adhesive fibers.

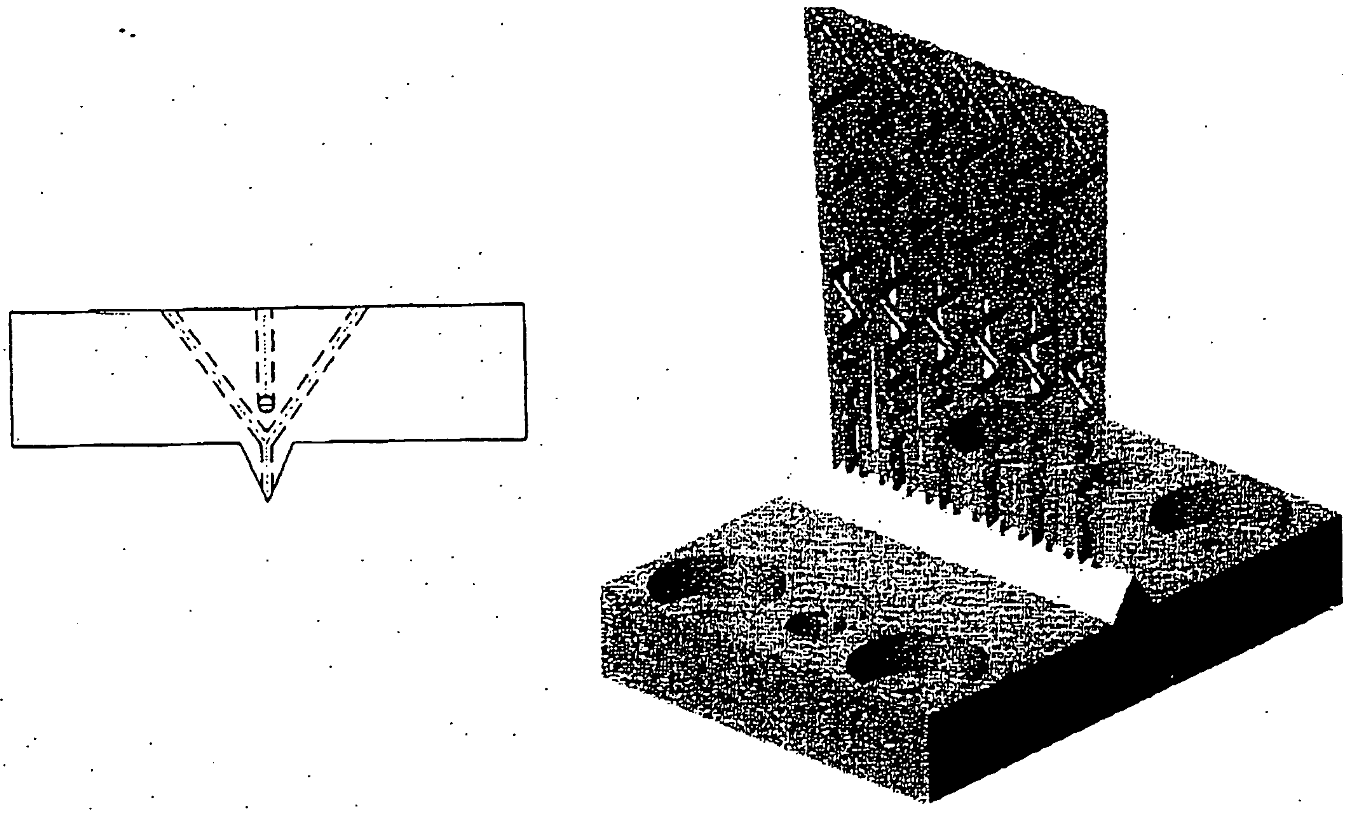
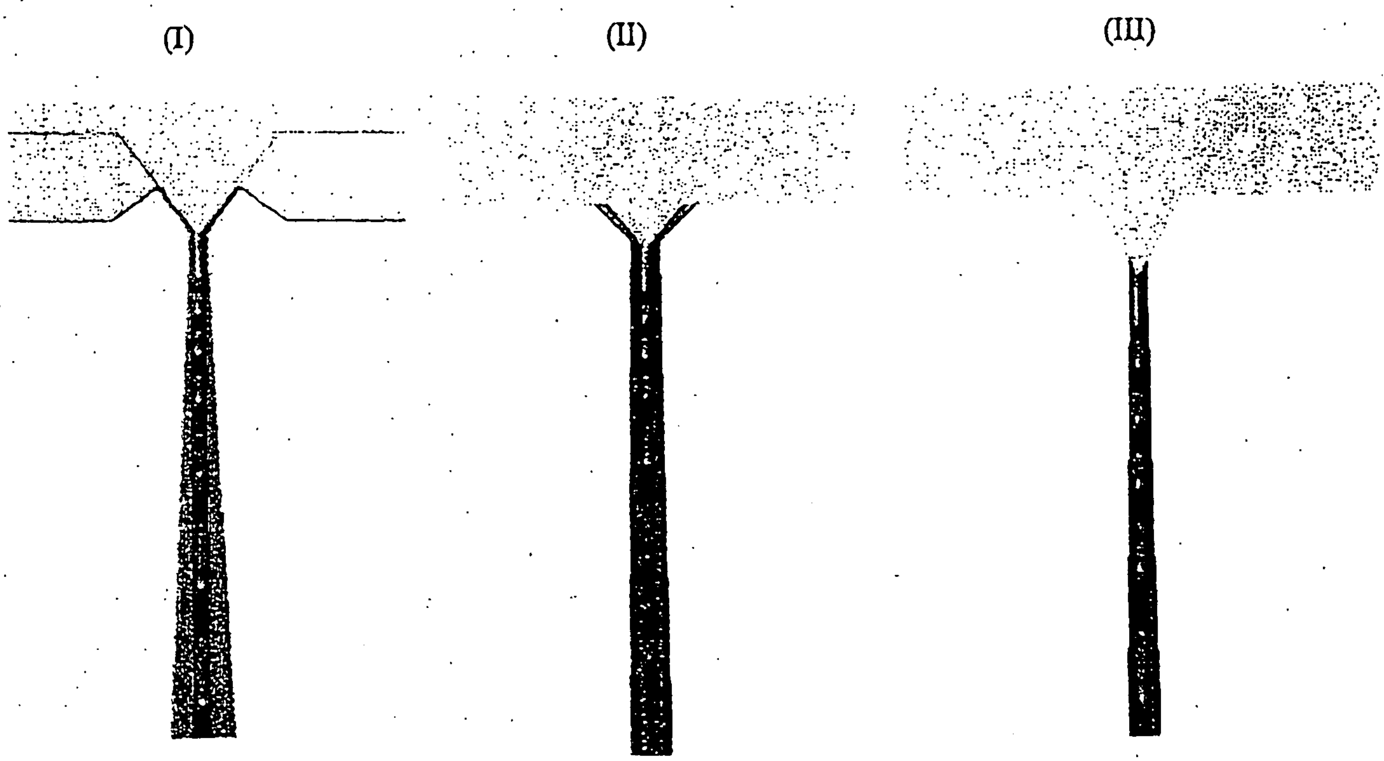


Figure: 6 (DuraStitch III Design)

This tip represents a novel method of fiberizing adhesives, while maintaining extreme pattern accuracy and unitary web or pattern construction, And again, no air plates were used, thus eliminating the debris problem. Less process air is used and random Meltblown or sinusoidal patterns can be obtained by merely changing process air pressure.

For comparison purposes the three DuraStitch development profiles are shown below:



3. Theory of Fiber Formation

Based on the extensive studies of adhesive Melt blowing technology, and the effect of the equipment designs, as discussed in section 2, it can be stated with certainty that lift, drag and eddys are clearly the underlying scientific and engineering principles of the Meltblowing process.

(a) Turbulent Flow and eddys

For straight air plates, the velocity profile in turbulent flow is flatter in the center region and steeper in the wall region than in laminar flow. This steeper velocity gradient near the wall creates a zone with instantaneous shear stress, which will produce turbulent eddys. Brodkey and Hershey (8) define the nature of eddys and state that eddys are random events so that the flow is not periodic in the sense of sine wave. The high velocity airflow contacts the low velocity airflow close to the outer wall region inside the air plate; a rotation results in the transverse vortex. This vortex increases in size with flow and moves away from the wall. This move has caused a bulge in the boundary layer edge. As the vortex accelerates away from the wall, another one must fill the space behind the first and repeat the cycle (10). Further out in the flow, the eddys are concentrated and help the melt flow to produce a sinusoidal pattern. The amount of eddys and the speed of their progress can be controlled to achieve either the random conventional Meltblowing pattern or the sinusoidal DuraStitch pattern types as shown in Figure 7.

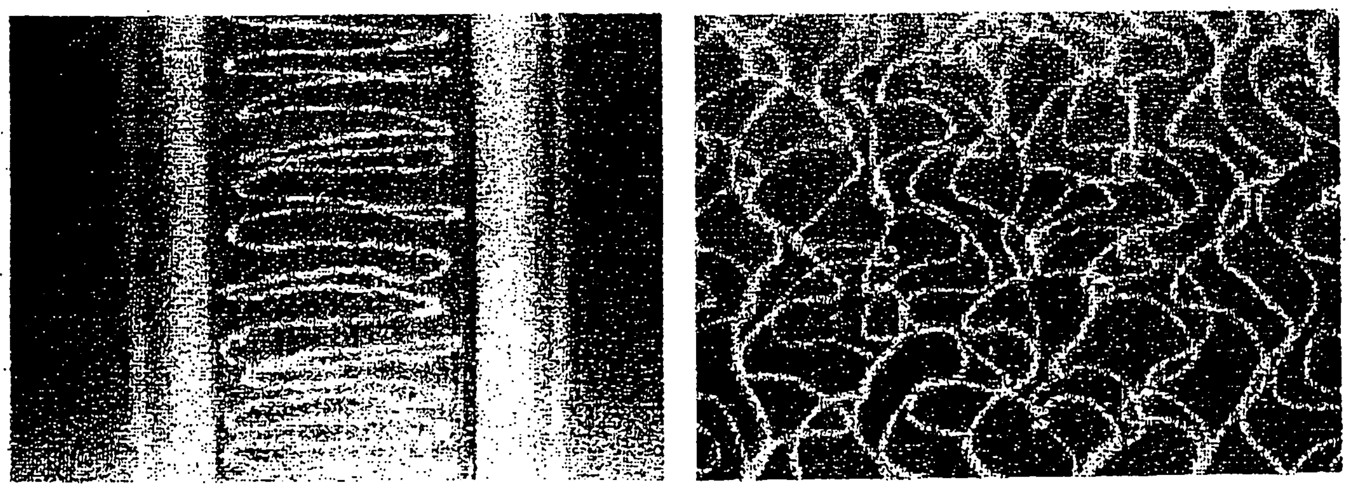


Figure: 7 (Sinusoidal DuraStitch pattern and Random Melt blown

According to Perry's Chemical Engineering Handbook (11) the velocity of a turbulent jet will decrease as it moves away from the nozzle, as shown in Figure 8. This figure is used to show that how rapidly the air velocity is becoming still air.

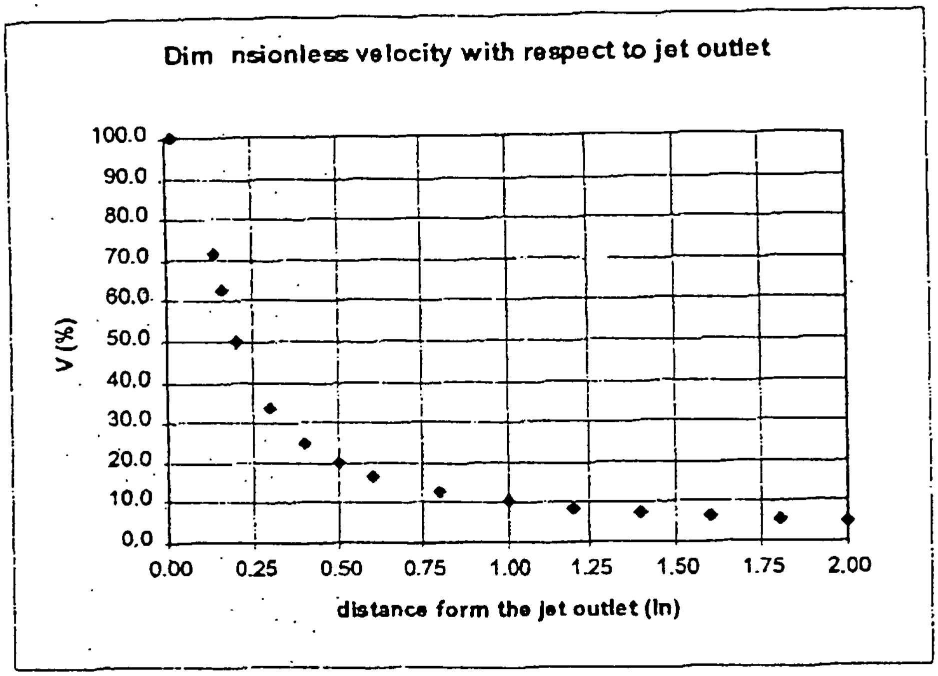


Figure: 8 (Dimensionless velocity vs. the distance away from the nozzle)

(b) Laminar Non-Newtonian Flow

Any fluid in which a plot of shear stress (τ) versus shear rate (-dv/dr) is not linear through the origin is a Non-Newtonian fluid. Such fluids can be "time independent" (eg. Mayonnaise, paints) or "time dependent" (e.g. thixotropic fluids). Some non-Newtonian fluids exhibit elastic behavior including elastic recovery from deformations that occur during flow. Polymer melts are good examples of such behavior in which part of the deformation is recovered upon removal of the stress-viscoelastic behaviors.

In most of non-Newtonian flow cases, power law or Ostwald / de Waele equation is used to correlate the shear stress and shear rate:

$$\tau = K \left(- \dot{\gamma} \right)^{n} \qquad (1)$$

Where K and n are the flow properties and $\dot{\gamma}$ is the (dv/dr), the shear rates. The velocity profile for non-Newtonian fluids can be written as:

$$\frac{v}{V_{max}} = \left[1 - \left(\frac{r}{R_0} \right)^{(n+1)/n} \right] \qquad (2)$$

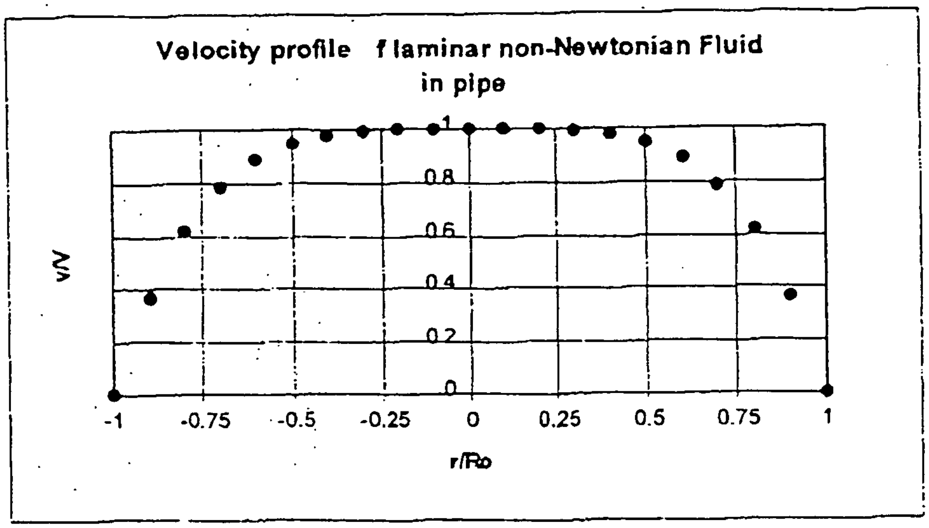


Figure: 9 (Velocity Profile of a non-Newtonian Fluid)

The profile shape will change with respect to the fluid parameter n. Figure 9 is an example for n=0.3. According to this analysis, a fully developed laminar flow will have zero velocity at the wall of a pipe. The length of pipe necessary for the development of the velocity profile can be calculated using

$$L_e = 0.0567 * d_o * N_{Re,non-Newtonian}$$

Where L_e is the entry length, $N_{Re;\ non-Newtonian}$ is the Reynolds number for non-Newtonian fluid.

(c) **Lift and Drag Forces**

Whenever an object is placed in a moving fluid, it will experience a force in the direction of the motion of the fluid relative to the object called drag force, DF and it may experience a force normal to the flow direction known as lift force, LF. These forces can be expressed as:

$$DF = C_D \left(\frac{\rho V^2}{2}\right) A$$

$$LF = C_L \left(\frac{\rho V^2}{2}\right) A \tag{3}$$

Where A is the characteristic area which is usually the surface area or the projected area normal to the flow direction. C_D and C_L are the drag coefficient and lift coefficient, respectively. Most of the cases, these coefficients must be experimentally determined and they are function of Reynolds Number:

$$C_D \propto f\,(\text{Re})$$
$$C_L \propto f\,(\text{Re}) \tag{4}$$

The drag due to tangential stresses is called skin friction or viscous drag. For any surface in contact with a flowing fluid, skin friction will exist. The skin friction coefficient C_f called non-dimensionalized wall shear stress can be calculated using the wall shear stress acting on the wall or surface by the fluid as:

$$C_f = \frac{2\,\tau_w}{\rho U^2} \tag{5}$$

Or using Matsui's (*Trans. Soc. Rheol.*, **26**, 465-473, 1976) model

$$C_f = 0.37 \times \left(N_{Re}\right)^{-0.61} \tag{6}$$

In addition to skin friction, if the flowing fluid is not parallel to the surface and it has to change directions to pass around a solid body, additional frictional losses will occur and this is called form drag. This drag is more important and often dominant for bluff bodies. As the fluid passes through the body, the boundary layer grows more rapidly. The large boundary layer or wake over the rear portion of the body results in a lower pressure and this reduced pressure on the rear portion of the body results in a net force in the direction of flow.

The total aerodynamic drag coefficient is found by experimentation or using tables or figures given by Research and Education Association "The Fluid Mechanics and Dynamics Problem Solver", Geankoplis "Transport Processes and Unit Operations", Hughes and Brighton "Fluid Dynamics".

In Figure 10, an example of viscous and aerodynamic drag forces on a filament with 20-micron diameter is given. The drag coefficient data is taken from Matsui Model (Goswami, "Manufactured Fibre Technology", Edited by Gupta and Kothari, Chapman & Hall, 1997) and from Research and Education Association" Fluid Mechanics and Dynamics Problem Solver". The air is assumed incompressible and has constant velocity all along the filament length.

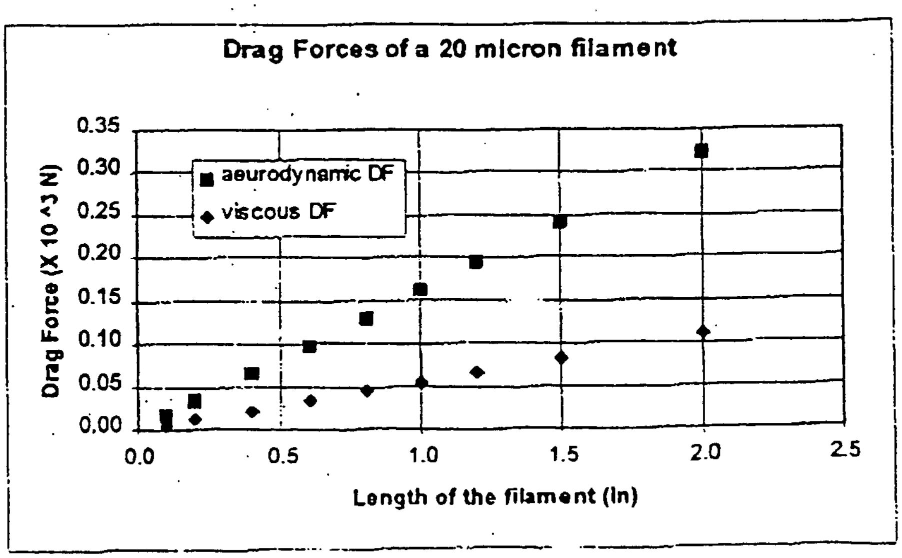


Figure: 10

In reality, the air velocity and the temperature of the air are decreasing with the distance, which will change the Reynolds number. For the calculation of the Reynolds number, the density and viscosity data are required. The density using ideal gas assumption and the viscosity using linear regression to the data given by Geankoplis "Transport Processes and Unit Operations" can be written as:

$$\rho_{air} = \frac{M_{air}\ P_a}{R\ T} = \frac{\left(28.97\ {}^{lb_m}/_{lbmol}\right)\left(14.697\ psia\right)}{\left(10.731\ {}^{psia\ ft^3}/_{lbmol\ R}\right)\left(\left(T+460\right)R\right)} \qquad (7)$$

$$\mu = 9.47 X 10^{-7}\ T + 6.44 X 10^{-4} \qquad with \quad R^2 = 0.9998 \quad (8)$$

These will change the Reynolds number values which is used in the calculation of viscous drag coefficient, C_f, given in equation (6). In this example, the air temperature has a -10° decrease, starting from 150° F, for every 0.2" length of the filament and the change in air velocity as given in Figure 9.

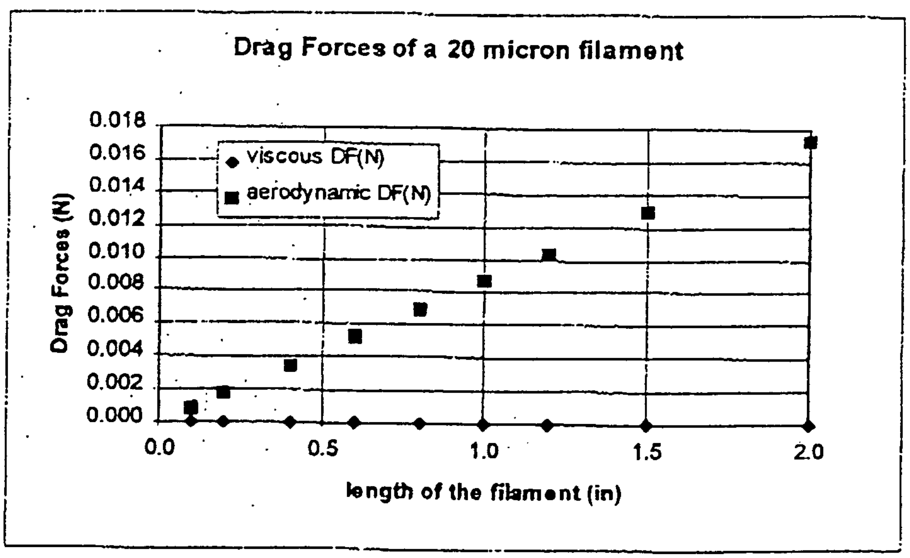


Figure: 11

Comparison of these two trials (Figure 11 and Figure 12) shows that in the case of the compressible flow, the calculated viscous drag force values are much less than the aerodynamic drag. The viscous drag is also given in Figure 12.

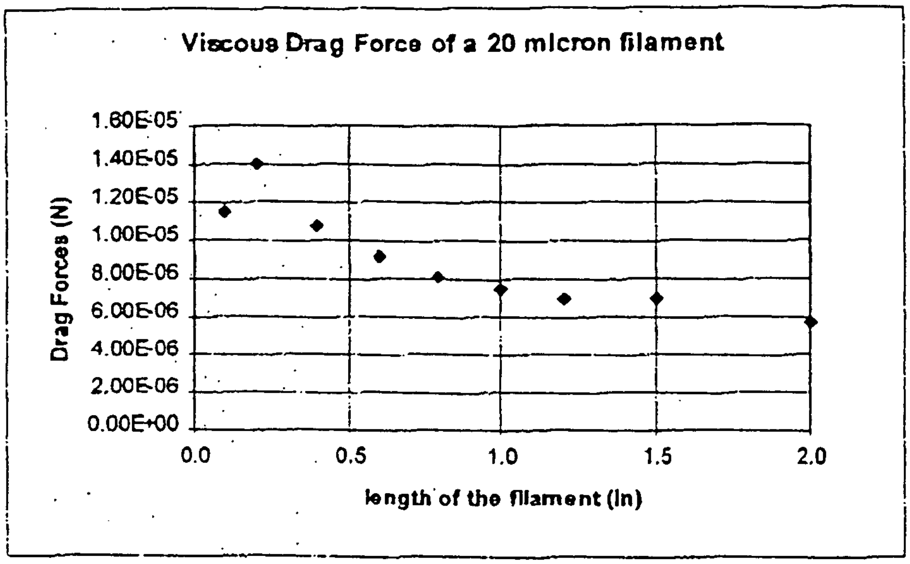


Figure: 12

Lift can be analyzed in the same way as drag and the lift coefficient is obtained empirically for lifting bodies as a function of attack angle, α. The attack angle is the angle between the airflow and melt flow. The combination of the lift force and the aerodynamic drag force causes the filament to oscillate in the cross direction of the web or substrate as shown in Figures 3 and 6.

(d) Conclusion – Fiber Formation Principles

As shown above, the key factors that need to be understood concerning fiber formation in the Melt blowing process are "eddy formations", and "lift" and "drag" forces. The drag due to tangential stresses is called "skin friction" or "viscous drag", which can be calculated using the earlier referenced articles. In addition to viscous drag, if the flowing fluid is not parallel to the surface, which it will not be due to eddy formation, additional frictional losses will occur as it changes direction to pass around the solid body (adhesive fibers) and this is called "aerodynamic" or "form" drag. Form drag is generally more important than viscous drag, as shown in figures 10 & 11. In fact, for a compressible fluid, viscous drag is negligible. The total aerodynamic drag coefficient is found by experimentation, or by consulting the reference tables. Lift can be analyzed as described earlier, and the combination of the lift force and the aerodynamic drag force causes the fiber to oscillate in the cross direction of the web, or substrate as shown in figure 3. When the selected process air volume is small, only lift and drag forces affect the melt exiting the orifices, and hence the resultant pattern is highly sinusoidal and controlled, which manifests itself as a "Stitching" pattern we refer to as DuraStitch. By increasing the process air volume, the resultant velocity and volumetric change, coupled with inherent geometric form produce "eddys" which increase "form" drag which will result in the conventional, random Melt blowing pattern. The DuraStitch technology distributes adhesive in a more even manner than the spiral or conventional Melt blowing methods. The patterns exhibit higher filament frequency than spiral, with reliability, robustness and longevity of the Melt blowing process.

4. Other Advances in Adhesive Melt blowing Technology

Although this article has concentrated on the technology advances in proceeding from AMBI to DuraStitch III, other advances have been made.

- J&M's fiberized element coating technology is able to provide users with the flexibility to run Polyurethane (PUR) type adhesives for several days without purging the system at the end of each day.
- Invisible Ply-bonding equipment.
- Bag gluing equipment.
- Multiple heads (Duralink) equipment for users with limited space.
- Other auxiliary equipment (Drum unloaders, Adhesive melters, Hoses, etc.)
- Coater/ Laminators, including the "SAMAS Laminator.

5. Overall Conclusions

The development over the last decade of Melt blowing adhesive technology and advanced equipment for the practice of this technology has been summarized. It has been clearly shown that: "Lift, drag and eddys" are primary scientific and engineering principles determining the fiber formation in either the polymer or adhesive Melt blowing process. Innovative equipment has been recently perfected for applying adhesives in a sinusoidal pattern, in a very cost effective manner, but which can be readily modified to produce conventional, random Melt blowing pattern by increasing the process air volume. With this basic understanding of the Melt blown technology, coupled with proper design and operation of such equipment, it can confidently be concluded that the Melt blowing process can:

- Provide users a very wide selection of fiber sizes from many different resins.
- Provide controlled, fully acceptable, different patterns, as a function of air volume.
- Provide patterns/ webs with very little "shot".
- Be operated with one to many melt filament orifices.

These advancements in both theory and equipment will continue to serve the growth of the very versatile Melt blowing process over the next several decades.

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